Two wavelength heterodyne absolute ranging technique using suppressed carrier modulation

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ABSTRACT

For interferometric distance measurements on rough surfaces multiple wavelength interferometry is a powerful tool. It allows to reduce the sensitivity and to extend the range of unambiguity for interferometric measurement. A new kind of a double wavelength heterodyne interferometer is presented which uses only one laser source which generates two wavelengths λ_1 and λ_2 simultaneously. The two different heterodyne frequency shifts of the double heterodyne interferometer (DHI) are achieved by combining an acousto-optical modulator (driven in suppressed carrier mode) with a fixed diffraction grating. In a first prototype a multi-wavelength HeNe laser was used as light source. The synthetic wavelength Λ in this system is 55.5 µm and the resolution about 0.15 µm. Measurement results obtained with the setup described are presented .

1. INTRODUCTION

Applying interferometric technique to the analysis of optically rough surfaces two serious problems arise. When using a reflection set-up the unambiguity range of the measurement is limited to the half laser wavelength. In addition the speckle effect makes measurements very difficult or even impossible. To overcome these problems interferometers with grazing incidence[1] or increased laser wavelength[2] were developed. Alternatively double heterodyne interferometry is used.

By applying two wavelengths simultaneously to the object the sensitivity is reduced to an effective wavelength[3,4] given by $\Lambda = \lambda_1 \cdot \lambda_2 / |\lambda_1 + \lambda_2|$. Fercher et al.[5] described a two wavelength heterodyne speckle interferometer where the phase of the effective wavelength is evaluated from two independent detector signals. In this paper a scanning double heterodyne technique is described that generates a low frequency detection signal with a phase shift that corresponds to the effective wavelength.

2. PRINCIPLE OF SUPRESSED CARRIER MODE

Double heterodyne interferometry (DHI) is based on two independent, coaxial and simultaneously working heterodyne interferometers with different frequencies ν_1, ν_2 and different heterodyne frequencies f_1 and f_2. The phase of the beat frequency $f_1 - f_2$ depends on the synthetic wavelength Λ and can therefore be examined for distance evaluation[6].

In fig. 1 a multi-wavelength HeNe laser is shown which emits simultaneously at 632.8 nm and 640.1 nm leading to a synthetic wavelength of Λ = 55.5 µm. The following acousto-optical modulator (AOM) is used to shift the basic frequencies ν_1 and ν_2 by the amount of the heterodyne frequency f_1 resp. f_2. To achieve this shift by the particular frequency in one step the acousto-optical modulator is driven with two different frequencies simultaneously (supressed carrier mode). Corresponding to the refraction index variations caused in the AOM two diverging first diffraction orders with the frequencies $\nu_1 + f_1$, $\nu_2 + f_1$, $\nu_1 + f_2$ and $\nu_2 + f_2$ occur. These two beams are chromatically separated with a matched grating. If one choses a spatial frequency which causes a diffraction angle which is equal the difference of the two first order diffraction angles of the

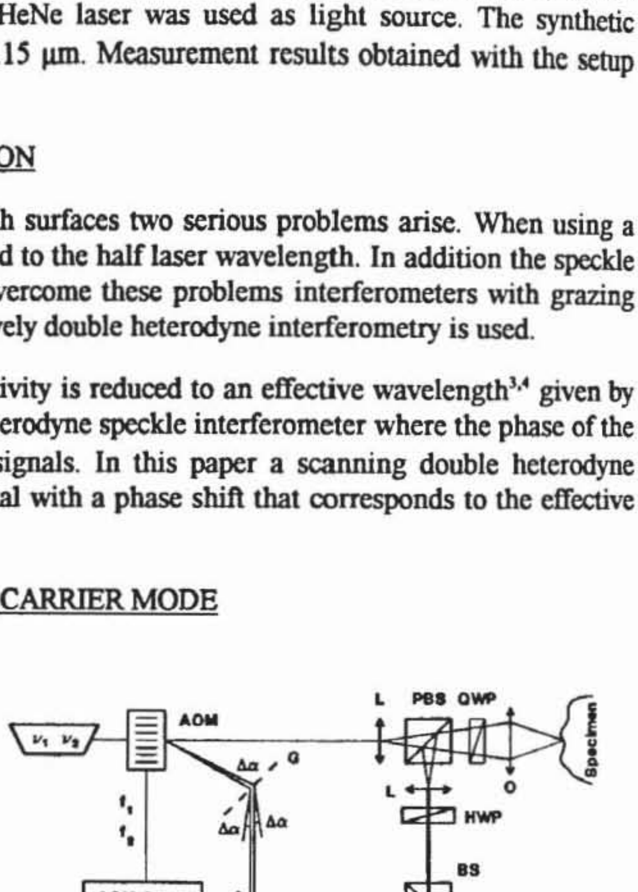

Fig. 1: Experimental set-up

AOM the beams $\nu_1 + f_1$ and $\nu_2 + f_2$ are coaxial. After passing a lens (L), a polarizing beam splitter (PBS) and a quarter wave plate (QWP) the object beams are focused onto the specimen under test by a camera objectiv (O) as shown in fig. 1. The back travelling light passes the QWP a second time and is therefore reflected at the PBS. The beat of the two heterodyne signals can be observed after demodulating the amplitude modulated detector output. After DC cut off, demodulation and bandpassfiltering one gets

$$u(t) = U_0 \cdot \cos\left(2\pi\cdot\left(f_2-f_1\right)\cdot t - 4\pi\cdot\frac{d}{\Lambda}+\varphi_0\right)$$

The phase shift of this term corresponds to the effectiv wavelength Λ. The demodulated and bandpassfiltered signal is finally fed to a log-in-amplifier (LIA).

3. RESULTS

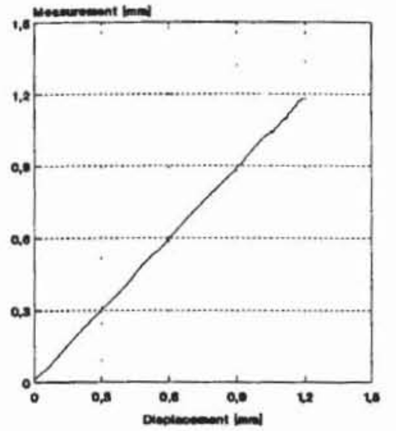

Fig. 2: Shift of a rough surface over a distance of 1.5 mm

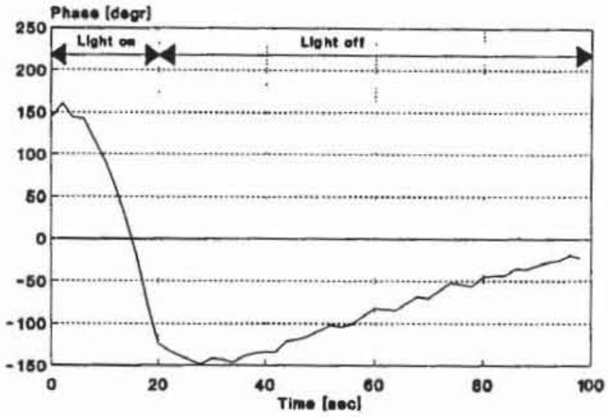

Fig. 3: Expansion of the base of a halogen lamp.

The first measurement of which the results are shown in fig. 2 was carried out to examine how far a rough surface can be moved in z-direction without refocusing the objectiv. The diagram shows the measured object displacement as a function of the stepper motor driven translation stage on which the object under test is mounted. Due to the fact that the translation stage carried out a continous movement ambiguity hopes in the phase can be removed. The unambiguity range of the measuring system is $\Lambda/2 = 27.7$ µm. During the measurement the amplitude of the signal is sufficiently high for the LIA. Consequently the object can be moved over 1.5 mm while it is not necessary to refocus.

Fig. 3 shows the expansion of the base of a halogen lamp caused by heating resp. cooling. When switching on the lamp the emitted heat causes an expansion of the base of about 11 µm in 20 sec. After switching off the lamp the expansion slows down first and then the effect negates. 70 sec. later the base cooled so much that the expansion decreased by 4 µm.

4. CONCLUSIONS

Double heterodyne interferometry has provided to be a powerful tool for precision interferometric measurements on optical rough as well as on smooth surfaces. The new method to generate the heterodyne frequency shifts with one acousto-optical modulator driven in supressed carrier mode was found out to be a very good solution especially because there are no mechanically moving parts which would affect the stability of the heterodyne frequencies.

5. REFERENCES

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